

## Introduction

### Chapter Background

This chapter addresses key aspects of the academic research and development (R&D) enterprise: financial resources, physical infrastructure, science and engineering (S&E) doctoral employment, financial support for S&E graduate education, and research outputs. Half a century ago, these same aspects were of sufficient concern to merit discussion in the two seminal reports focusing on the U.S. R&D system, *Science—The Endless Frontier* (Bush 1945) and *Science and Public Policy* (Steelman 1947).

Both the Bush and the Steelman reports stressed the critical importance of a Federal role in supporting academic research, recommending a major expansion of that role. Today, that vision has materialized. A strong national consensus supports the public funding of academic research, and the Federal Government provides roughly 60 percent of the financial resources for academic R&D. A number of contemporary issues have arisen relating to this support; the appropriate balance of funding across S&E disciplines and accountability requirements—including measuring outputs and larger social outcomes—are examples.

The Steelman report focused on an aspect of the academic R&D enterprise that has become an enduring concern: broadening and strengthening the academic base of the Nation's science and engineering and R&D enterprise. Talent was sure to be found everywhere, and the Steelman report recommended using a portion of National Science Foundation (NSF) funds to strengthen weaker but promising colleges and universities in order to increase U.S. scientific potential. In point of fact, the number of academic institutions receiving Federal support for R&D activities has increased dramatically since the issuance of the report.

The Steelman report also noted that research facilities were less adequate at universities and colleges than elsewhere and called for additional libraries, laboratory space, and equipment and for Federal aid to academic institutions for the construction of facilities and purchase of equipment. Except for a decade during the 1960s and early 1970s, when a number of agencies conducted broad institutional support programs, the Federal Government has not taken a major role in providing direct support to universities and colleges for the construction of their research facilities. In recent years, it has accounted for about 8 to 9 percent of the funds for laboratory construction and renovation, with the institutions providing over 60 percent. In contrast, the Federal Government has accounted for almost 60 percent of direct current funds expenditures for academic research equipment during the past two decades. The Federal Government also indirectly supports both facilities and equipment through reimbursement on Federal grants and contracts.

The Steelman report placed strong emphasis on human resources development. An early chapter bears the title "Manpower: The Limiting Resource" and noted a broad disparity in the growth paths of the Nation's R&D budget and highly

trained personnel. While recommending strong increases in R&D funding, the report recognized the need to alleviate inadequate personnel resources. It pointed to the critical role of doctoral science and engineering faculty in the universities and colleges, noting both their teaching and their research responsibilities. The report estimated that it would take an additional 15,000 such faculty to restore the prewar student-teacher ratio, while also expanding the sector's capacity for research. The discussion of these issues in recent years has been quite different, focusing on a burgeoning supply of new science and engineering Ph.D.s and a sometimes-variable labor market for other degree-holders, punctuated by debates about shortages and oversupply.

Both the Bush and the Steelman reports focused on an issue that has drawn increasing attention over the past decade—the importance of integrating education and research in higher education. They stressed that research is required for the teaching of science, and that fully trained scientists can only be produced through involvement in research. The Steelman report noted that the recommended expansion of academic research grants would result in the employment of graduate students as research assistants, which in turn would result in better scientific training. Research assistantships now comprise the largest primary graduate student support mechanism; two-thirds of federally supported students receive their support in the form of a research assistantship. A number of Federal graduate traineeship programs, and even more recently some Federal graduate fellowship programs, have emphasized the integration of education and research.

Half a century ago, the Steelman and Bush reports largely took for granted the positive outcomes and impacts of research and development. Today's mature and established publicly funded R&D system faces new demands, not envisioned then, of devising means and measures to account for the proximate outputs of specific Federal R&D investments, including those for academic R&D, and their longer-term consequences for valued social ends.

Even though the academic R&D enterprise has enjoyed strong growth for the past several decades, the Nation's universities and colleges face challenges in their finances, enrollment, faculty, and competitive environment. Many of these factors will have some form of impact on the academic R&D enterprise. This chapter seeks to provide data on some pertinent trends and analysis bearing on these issues.

### Chapter Organization

The chapter opens with a discussion of trends in the financial resources provided for academic R&D, including allocations across both academic institutions and S&E fields. Because the Federal Government has been the primary source of support for academic R&D for over half a century, the importance of selected agencies in supporting individual fields is explored in some detail. Data are also presented on changes in the number of academic institutions receiving Federal R&D support. The section then examines the status of two key elements of university research activities—facilities and instrumentation.

## Basic Research

### *Science and Public Policy (Steelman report)*

#### *Part One—Science for the Nation, IV. A National Science Program*

Basic research traditionally has been conducted in the colleges and universities. While industry engages in some basic research and the Government laboratories conduct a somewhat greater amount, the proportions in both instances are small. The principal function of the colleges and universities is to promote the progress of learning and they must be the primary means through which any expanded program of basic research is carried out. There are several reasons for this.

First, the scientific method, being based upon experiment, requires research for the teaching of science. Fully trained scientists can be produced only through practicing research.

Second, basic research is so broad in its application and so indirectly related to any industrial process, or in fact to

any particular industry, that it is not profitable for private enterprise to engage in extensive basic research. Industries do sometimes support it through fellowships and other grants to universities, but the sums involved are not large.

Third, research, while carried out by individuals, has always been a cooperative venture. Scientists have exchanged information and collaborated with each other in the performance of research; and science progresses characteristically through a combination of knowledge from many different sources. Research thrives in situations where scientists with many diverse interests and fields of knowledge can be brought together in an exchange of both knowledge and ideas. Thus the universities, which foster all branches of knowledge, are ideal breeding grounds for basic research. (Steelman 1947, 29.)

The next section discusses trends in the employment, demographic characteristics, and activities of academic doctoral scientists and engineers. The discussion of employment trends focuses on full-time faculty, postdoctorates, and other positions. Differences are examined between the Nation's largest research universities and other academic institutions, as are shifts in the faculty age structure. The involvement of women, underrepresented minorities, and Asians and Pacific Islanders is also examined. Attention is given to participation in research by academic doctoral scientists and engineers, the relative balance between teaching and research, and the Federal support they report for their research. Selected demographic characteristics of recent doctorate-holders entering academic employment are examined.

The third section looks at the relationships between research and graduate education. It covers overall trends in graduate support and patterns of support in different types of institutions, and compares support patterns for those who complete an S&E doctorate with the full population of graduate students. The role of graduate research assistantships is examined in some detail, including the sources of support for research assistants and the spreading incidence of research assistantship (RA) support to a growing number of academic institutions.

The chapter's final section deals with two research outputs: scientific and technical articles in a set of journals covered by the Science Citation Index (SCI), and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in the preceding section of this chapter and in chapter 4.) The section specifically looks at the output volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent scientific activity (citation patterns), and use beyond science (citations to the literature on patent applications). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

## Financial Resources for Academic R&D<sup>1</sup>

Academic R&D is a significant part of the national R&D enterprise. Enabling U.S. academic researchers to carry out world-class research requires adequate financial support as well as excellent research facilities and high-quality research equipment. Consequently, assessing how well the academic R&D sector is doing, the challenges it faces, and how it is responding to those challenges requires data and information relating to a number of important issues that relate to the financing of academic R&D. Among these issues are the level and stability of overall funding; the sources of funding and changes in their relative importance; the distribution of funding among the different R&D activities (basic research, applied research, and development); the balance of funding among science and engineering fields and subfields or fine fields; the distribution of funding among and the extent of participation of various types of academic R&D performers; the changing role of the Federal Government as a supporter of academic R&D and the particular roles of the major Federal agencies funding this sector; and the state of the physical infrastructure—research facilities and equipment—that is a necessary input to the sector's success. This section focuses on providing data on these aspects of the academic R&D enterprise which individually and in combination influence its evolution.

<sup>1</sup>Data in this section come from several different National Science Foundation (NSF) surveys that do not always use comparable definitions or methodologies. NSF's three main surveys involving academic R&D are the (1) Survey of Federal Funds for Research and Development; (2) Survey of Federal Science and Engineering Support to Universities, Colleges, and Non-profit Institutions; and (3) Survey of Research and Development Expenditures at Universities and Colleges. The results from this last survey are based on data obtained directly from universities and colleges; the former two surveys collect data from Federal agencies. For descriptions of the methodologies of these and other NSF surveys, see NSF (1995b and 1995c). Federally Funded Research and Development Centers associated with universities are tallied separately and are examined in greater detail in chapter 2.